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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : F23G 5/027

A1

(11) International Publication Number: WO 99/04197

(43) International Publication Date: 28 January 1999 (28.01.99)

(21) International Application Number: PCT/GB98/02098

(22) International Filing Date: 16 July 1998 (16.07.98)

(30) Priority Data:
9714983.5 16 July 1997 (16.07.97) GB

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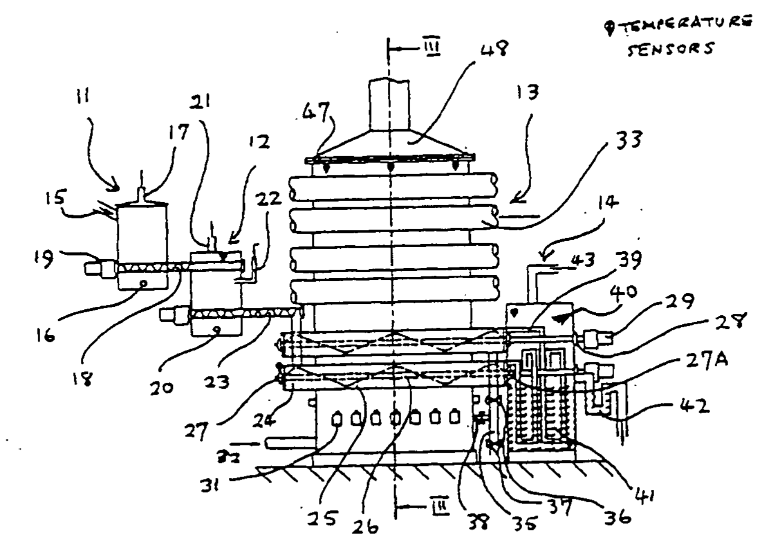
(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, HR, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

– nicht selbe Beheizg
– undifferenziert

(54) Title: RECOVERY OF ENERGY



(57) Abstract

A process for the recovery of energy values from waste biodegradable material comprises passing comminuted waste material through a pyrolysis reaction chamber (13) and cooling the gaseous pyrolysis reaction product, in which the pyrolysis (24) and cooling chambers (14) are adjoining and the waste material is advanced through the pyrolysis chamber by advancement means comprising rotary drive shaft means (25) sealingly journalled through the wall of the cooling chamber remote from the pyrolysis chamber. The drive shaft gland (28) is therefore removed from direct exposure to the heat of the pyrolysis reaction and higher pyrolysis temperatures can therefore be tolerated, with a greater ability to treat biologically-active waste or other hazardous materials and a significantly faster processing time being achieved.

RECOVERY OF ENERGY

This invention relates to the recovery of energy and is especially concerned with the recovery and use of energy values as fuel from waste material. Waste material in the context of the present invention includes all forms of biodegradable waste materials including sewage, rubber tyres and printed circuit boards.

Society currently generates large volumes of domestic and industrial waste material which creates environmental problems in terms of storage or disposal, for example by incineration. Tyres and printed circuit boards in particular present disposal problems. Modern society also consumes large amounts of energy which to a large extent is generated by combustion of fossil fuels, creating environmental problems in terms of production of so-called "greenhouse gases" as a by-product.

WO 93/25848 proposes production of gaseous fuel by heating waste material in a rotating drum without allowing combustion to take place and using the fuel to generate electricity. At least some of the fuel produced may be used to heat the waste material. However, the temperature of the gasifier is approximately 800°C which is insufficient for safe treatment of hospital waste.

BSE-contaminated carcasses and other biologically-active waste. Also, the processing speed is insufficiently fast to permit flexibility in plant operation to account for variables in terms of quantity and quality of waste material to be processed.

It is an object of the present invention to provide a method and apparatus for recovery of energy values from waste material which can operate at temperatures sufficiently high to enable biologically-active waste to be safely disposed of, and which is more efficient and more environmentally-acceptable than prior art proposals, and which permits greater flexibility of plant operation.

According to one aspect of the present invention, a process for the recovery of energy values from waste biodegradable material comprises passing comminuted waste material through a pyrolysis reaction chamber and cooling the gaseous pyrolysis reaction product, in which the pyrolysis and cooling chambers are adjoining and the waste material is advanced through the pyrolysis chamber by advancement means comprising rotary drive shaft means sealingly journalled through the wall of the cooling chamber remote from the pyrolysis chamber.

By virtue of the inventive arrangement of the pyrolysis and cooling chambers, the drive shaft gland is

removed from direct exposure to the heat of the pyrolysis reaction and higher pyrolysis temperatures can therefore be tolerated, with a greater ability to treat biologically-active waste or other hazardous materials and a significantly faster processing time being achieved.

Preferably, the flue gases heating the waste material in the pyrolysis operation are passed to a heat exchanger to produce steam for generation of electricity, thereby cooling the flue gases before they are vented to atmosphere and providing an environmental benefit.

The pyrolysis gaseous product may be used as fuel for a gas turbine electricity generator or for one or more gas-fired boilers for production of steam and in either case the exhaust gases, which can be at temperatures as high as 2000°C, can also be passed to the or a heat exchanger for production of steam. The gaseous pyrolysis reaction product may also be stored and optionally transported for eventual use elsewhere as fuel gas.

The raw waste material is initially sorted or screened to remove metallic materials, glass and other ceramic materials, and bricks, concrete and the like. The resulting combustible or carbon-containing material, which may contain up to 40% or more water, is preferably then dried and comminuted by a shredding, crushing, pulverising

or other operation to provide the material in particulate, granular or other individual-piece form to assist in substantially complete pyrolysis. Any non-volatile liquids such as oils, grease or fats may be used as such in the pyrolysis reaction or admixed with the solid material. Before being passed to the pyrolysis reactor, the dried and comminuted material optionally containing non-volatile liquids is preferably pre-heated and de-oxygenated. The material is then fed to the pyrolysis reaction chamber which may have a temperature in excess of 1000°C where it is preferably agitated or tumbled to assist in even distribution in the reactor and rapid chemical breakdown and gasification. Optionally, liquids such as used engine oil are added to the feed material to increase the calorific value thereof.

Preferably, the water vapour recovered from the drying of the waste material is added to the fuel for the pyrolysis reaction or for the gas boiler or boilers to increase the combustion efficiency of the fuel, and/or used in the cooling stage. At least a portion of the gaseous product may be used as process gas for the pyrolysis reactor as well as for the gas turbine and/or gas-fired boilers.

Discharge gases from the boilers may be used via suitable heat-exchange means to preheat the return water from the condensers to the boilers; after the gases have passed through such heat-exchange means, any residual heat may be used to dry the raw waste material prior to storage in silos. The resulting water-containing air may be condensed and passed to a desalination plant. The cooling water from the condensers may also be used to operate a desalination plant.

In another aspect, the invention provides apparatus for the recovery of energy values from biodegradable waste material, the apparatus comprising a pyrolysis reaction chamber and a cooling chamber and means for advancing said material in comminuted form through the pyrolysis reaction chamber, in which the pyrolysis and cooling chambers are adjoining and the advancing means comprise rotary drive shaft means sealingly journalled through the wall of the cooling chamber remote from the pyrolysis chamber.

Optionally, the apparatus includes gas turbine means and/or gas-fired boiler means to generate electricity from the pyrolysis reaction product gases, and a desalination plant operatively connected to the exhaust from the turbines or condensers. The apparatus may also include

means to pass the flue gases from the pyrolysis reactor to a heat exchanger for production of steam for generation of electricity.

Preferably, the pyrolysis reactor comprises a tubular reactor body containing a rotary screw and mixing element to advance the pyrolisable material from an inlet station through a heated reactor zone to an outlet station for gaseous product. The use of such a reactor avoids the need for gaseous seal elements in or close to the reactor zone and this enables considerably higher reactor temperatures, typically in excess of 1000°C, and up to about 1500°C, to be employed, compared with reactors such as disclosed in WO 93/25848 which employ rotating drums which require rotary seal elements and glands and hence cannot operate at temperatures in excess of approximately 800°C. The use of higher pyrolysis temperatures enables the process to be operated with toxic raw materials including hospital waste, BSE-contaminated animal carcasses and the like. Another advantage of a rotary screw element carried within a tubular reactor body is that any char or other solid or liquid residue including precious metal values from the raw material or the pyrolysis reaction is carried through the reactor and discharged therefrom at the outlet station. Preferably,

solid or liquid residue is discharged upstream of the outlet station, that is, while still substantially at pyrolysis temperature. The direct connection of the cooling means to the outlet station facilitates rapid cooling with minimum opportunity for any chemical re-combination of the pyrolysis reaction product gases, as well as enabling the use of the higher temperature by virtue of the journalling of the rotary drive shaft means.

The pyrolysis reaction gaseous product may be recovered and stored by quenching in a water spray and passed to a storage cylinder by displacement of water, which may be the water recovered from the raw material drying process.

The process and apparatus according to the invention may readily be adapted for automated control, in that temperature sensors, calorific value sensors, throughput sensors and the like may be operatively connected to control the variables of the system including input calorific value, rotary speed of the advancement means, pyrolysis temperature, cooling temperature and control of extracted water vapour to the burners.

Embodiments of the invention will now be described by way of example with reference to the accompanying drawings, of which:

Figure 1 is a side elevation in diagrammatic form of a pyrolysis conversion apparatus;

Figure 2 is an elevation of the apparatus of Figure 2 from the feed end; and

Figure 3 is a section through the apparatus along the line III-III of Figure 1.

In more detail, the apparatus includes a pre-heater unit 11 for raw material in pelletized form, a heater/deoxygenator unit 12, a pyrolysis reactor unit 13 and a cooling unit 14. The pre-heater unit 11 has an upper inlet pipe 15 for pelletized raw material, a lower inlet 26 for hot oxygen-free gases, optionally flue gases from the pyrolysis reactor unit 13, to pre-heat the pellets and begin the process of oxygen removal therefrom, and a chimney 17 for waste gases; the chimney is connected to a condenser (not shown) for recovery of water vapour or water vapour is passed as such to the pyrolysis furnace. The pellets are transported to the upper part of heater/deoxygenator unit 12 by screw conveyors or augers 18 driven by variable-speed geared electric motors 19; the process of pre-heating, oxygen removal and drying is completed in this unit by passing hot oxygen-free gas in at 20 and removing waste gases through chimney 21, again connected to a condenser (not shown) or utilised per se in

the burner feedstock. Waste oil or other liquid of high calorific value may be introduced through pipe 22, suitably provided with a seal (not shown) to prevent ingress of air.

The finally dried and heated raw material is then passed by screw conveyors 23 to the upper part of one or more (three in the embodiment illustrated) substantially horizontally-disposed pyrolysis converter tubes 24, containing a rotary paddle-type stirrer/mixer 25 which also acts as a relatively long-pitch screw conveyor to transport raw material through the converter. The converter tubes may optionally be disposed at a slight downward angle (away from the feed end) to assist in transportation of pyrolysis material. The mixers 25 are carried on shafts 26 journalled internally of the converter tubes in end cap/bearing units 27 at the proximal or feed end and extending through bearing/seal units 28 at the remote end of the cooler unit 14, and are rotatably driven by variable-speed geared electric motors 29. An intermediate bearing unit 27A is provided where the shafts pass through the common or adjoining end walls of the pyrolysis tubes and the cooler unit; such bearings do not have to have a sealing function and hence can readily withstand high pyrolysis temperatures. The end

bearing/seal units 28 are not only removed from the high pyrolysis temperatures but are also cooled by incoming cooling water, as hereinafter described. The converter tubes 24 are carried in a heater furnace 30 where they are heated by hot gases from gas-fuelled burners fed by pressurised gas jets 31; moist air may be fed in at 32 to improve combustion performance. The combustion gases after passing over and around the converter tubes are passed through a heat exchanger containing tubes 33 and baffles 34 to produce stream for turbines or for use in boilers; the stream condensate may be a closed loop system with no requirement for replenishment water.

The distal ends of the pyrolysis converter tubes, downstream of the heater furnace, are lagged and provided with drain or residue pipes 35 controlled by upper and lower valves 36, 37 and including, between the valves, a valved connection 38 to the furnace 30, whereby any ash (which should not occupy any substantial volume if the pyrolysis reaction has been properly controlled) including non-combustible, for example metallic, residues can be drawn off without allowing ingress of air, any gases being returned to the furnace 30 through connection pipe 38. The pyrolysis reaction gases are passed through pipes 39 direct to the cooler 14 fed with a water inlet 40 and

containing a constant-head volume 41 of water controlled by a weir and trap arrangement 42 to prevent gas escape. The cooled gases are then passed through outlet pipe 43 to be compressed and stored. Outlet pipe 43 may contain a calorific value sensor or monitor (not shown) which can be used optionally with automatic comparator/feedback means to control input of oil through pipe 22.

The apparatus may as illustrated by constructed and assembled from mating modular parts or sub-assemblies, for example as defined by cooperating flanges 44 between the burner and converter sections, 45 between the converter and lower part of the heat exchanger and 46 between the lower and upper parts of the heat exchanger. The top flange joint 47 is between the upper part of the heat exchanger and the roof/flue 48.

The materials of constructions are chosen according to the intended-temperature of operation and the nature of the raw material and may be selected from metallic materials including high temperature-resistant alloys capable of withstanding corrosive or other aggressive environments and ceramic materials; especially porous ceramics.

The invention allows higher pyrolysis temperatures to be achieved than has hitherto been possible by virtue of

the stationary pyrolysis tubes being attached direct to the cooling unit with the resulting possibility of sealingly journalling the rotary advancement means away from the hot zone. Faster processing times are another benefit, with the possibility of flexibility of plant operation according to instantaneous requirements dictated for example by the quality or nature of the feed material, since pyrolysis reaction speed ceases to be the overall rate determining step.

CLAIMS:

1. A process for the recovery of energy values from waste biodegradable material, the process comprising passing comminuted waste material through a pyrolysis reaction chamber and cooling the gaseous pyrolysis reaction product, in which the pyrolysis and cooling chambers are adjoining and the waste material is advanced through the pyrolysis chamber by advancement means comprising rotary drive shaft means sealingly journalled through the wall of the cooling chamber remote from the pyrolysis chamber.

2. A process to claim 1, in which the flue gases heating the waste material in the pyrolysis operation are passed to a heat exchanger to produce steam for generation of electricity.

3. A process according to claim 1 or claim 2, in which the raw waste material is initially sorted or screened to remove metallic materials, glass and other ceramic materials, and bricks, concrete and the like.

4. A process according to any preceding claim, in which the waste material is dried and comminuted to provide the material in particulate, granular or other individual-piece form.

5. A process according to any preceding claim, in which any non-volatile liquids such as oils, grease or fats are used as such in the pyrolysis reaction or admixed with the solid material.

6. A process according to any preceding claim, in which the raw material is pre-heated and de-oxygenated.

7. A process according to any preceding claim in which a liquid such as used engine oil is added to the feed material to increase the calorific value thereof.

8. A process according to any of claims 4 to 7, in which the water vapour recovered from the drying of the waste material is added to the fuel for the pyrolysis reaction or for the gas boiler or boilers to increase the combustion efficiency of the fuel, and/or used in the cooling stage.

9. A process according to any preceding claim, in which the temperature of the pyrolysis reactor is in the range 1000-1500°C.

10. Apparatus for the recovery of energy values from biodegradable waste material, the apparatus comprising a pyrolysis reaction chamber and a cooling chamber and means for advancing said material in comminuted form through the pyrolysis reaction chamber, in which the pyrolysis and cooling chambers are adjoining

and the advancing means comprise rotary drive shaft means sealingly journalled through the wall of the cooling chamber remote from the pyrolysis chamber.

11. Apparatus according to claim 10, in which the apparatus includes gas turbine means and/or gas-fired boiler means to generate electricity from the pyrolysis reaction product gases, and a desalination plant operatively connected to the exhaust from the turbines or condensers.

12. Apparatus according to claim 10 or claim 11, in which the pyrolysis reactor comprises a tubular reactor body containing a rotary screw and mixing element to advance the pyrolisable material from an inlet station through a heated reactor zone to an outlet station for gaseous product.

13. Apparatus according to any of claims 10 to 12, in which the pyrolysis reaction chamber forms part of a converter/heat exchanger unit assembled from mating modular parts or sub-assemblies.

14. A process for the recovery of energy values from waste material, the process comprising drying and comminuting the waste material, subjecting the comminuted waste material to a pyrolysis operation, cracking and cooling the gaseous pyrolysis reaction product and storing

said product, in which the flue gases from the pyrolysis reaction are passed to a heat exchanger to produce steam for generation of electricity.

15. Apparatus for the recovery of energy values from waste material, the apparatus comprising means for drying and comminuting the waste material, means for passing said material to a pyrolysis reactor, means for cracking and cooling the pyrolysis reaction product and means to pass the flue gases from said pyrolysis reactor to a heat exchanger for production of steam for generation of electricity.

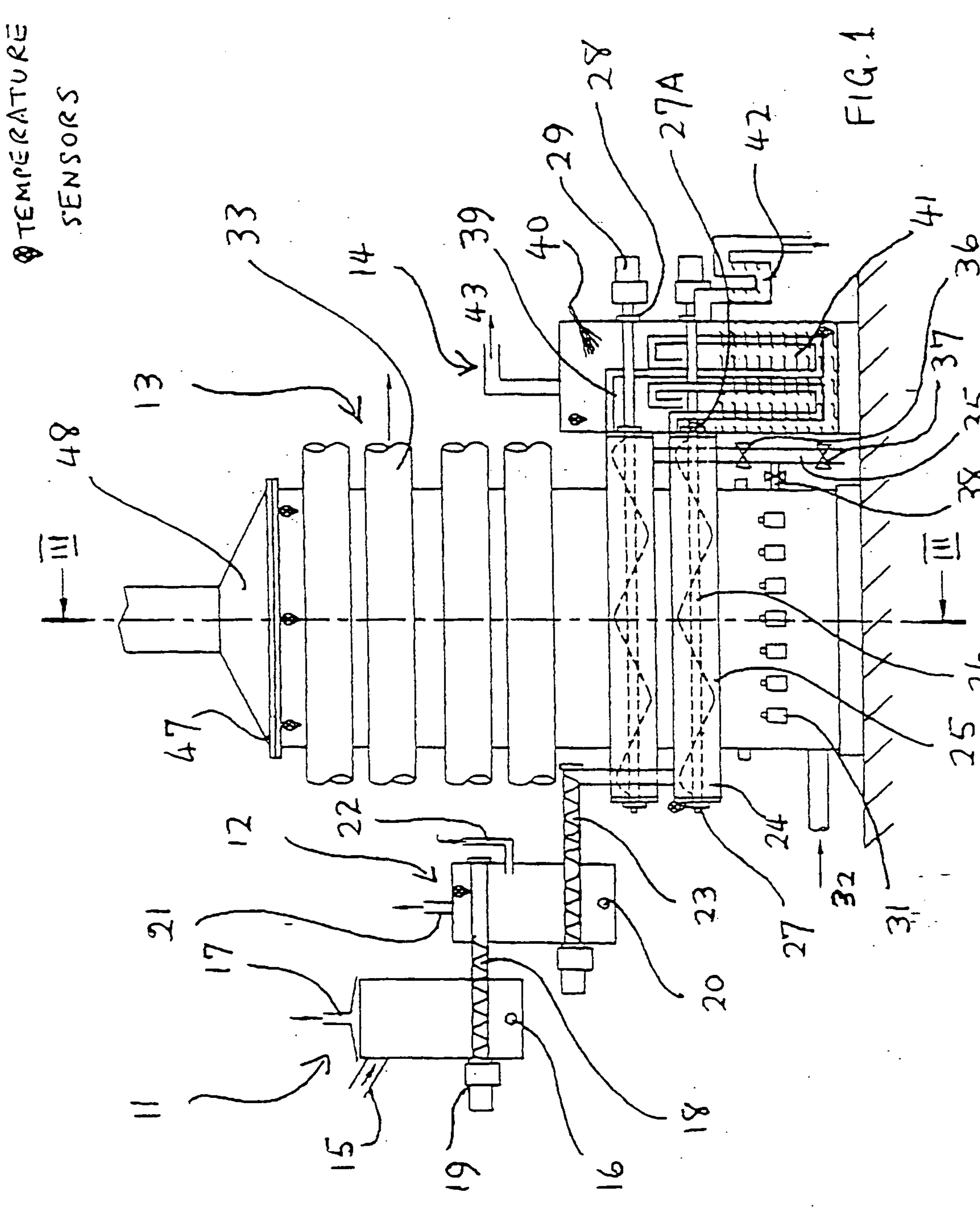

TEMPERATURE SENSORS
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FIG. 1

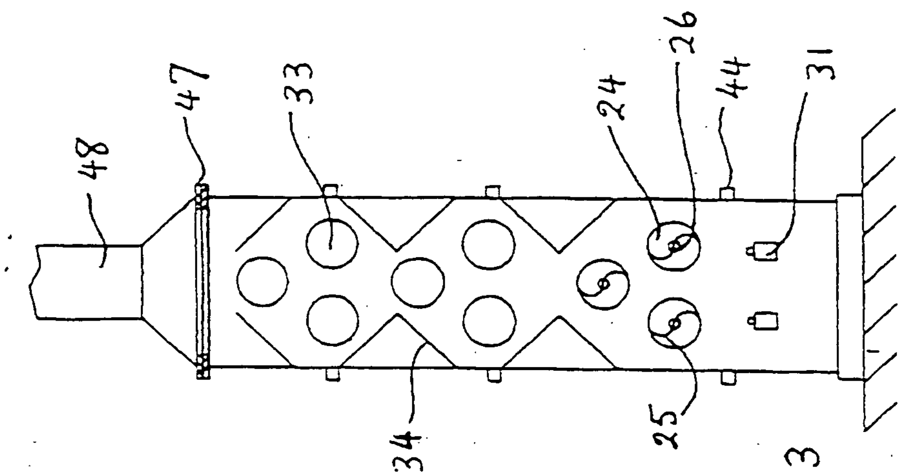

FIG. 3

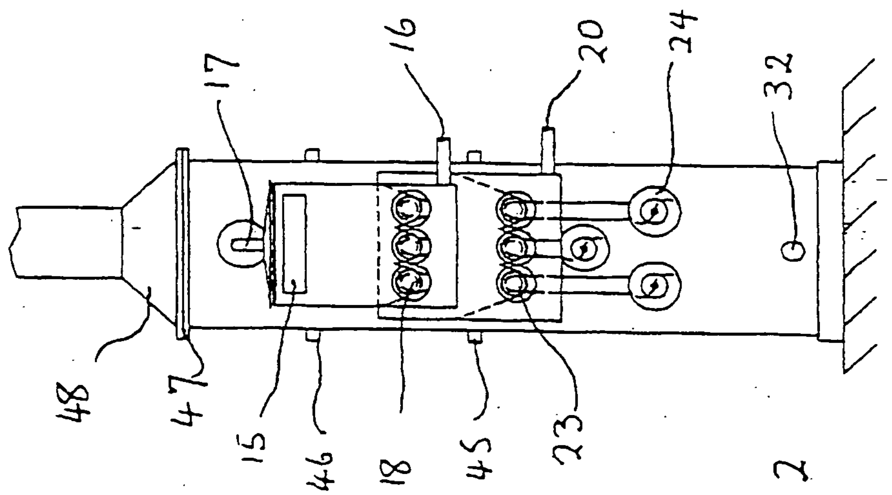

FIG. 2

INT ATIONAL SEARCH REPORT

Intern[redacted]l A ·ation No
-CT/GB 98/02098

A. CLASSIFICATION OF SUBJECT MATTER

F 23 G 5/027

According to International Patent Classification (IPC) or to both national classification and IPC6

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F 23 G,C 10 B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4217175 A (REILLY, B.B.) 12 August 1980 (12.08.80), column 6, last chapter, column 7, sentence 1, column 4, lines 41-47,1-7, column 2, lines 63-67, column 5, lines 41-43, fig. 1,5. --	1,2,3, 4,5,9, 10,12, 14,15
A	DE 3717542 A1 (KRUPP POLYSIUS AG) 15 December 1988 (15.12.88), column 2, lines 60-63, fig.. --	10
A	US 4732091 A (GOULD, O.E.) 22 March 1988 (22.03.88), column 1, chapter 1,	1,10, 11

[X] Further documents are listed in the continuation of box C.

[ ] Patent family members are listed in annex.

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Date of the actual completion of the international search
03 November 1998

Date of mailing of the international search report
04.12.1998

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	chapter 6, lines 45-48, column 4, lines 61-65. ----	

ANHANG	ANNEX	ANNEXE
zum internationalen Recherchenbericht über die internationale Patentanmeldung Nr.	to the International Search Report to the International Patent Application No.	au rapport de recherche international relatif à la demande de brevet international n°

PCT/GB 98/02098 SAE 203086

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Im Recherchenbericht angeführtes Patentdokument Patent document cited in search report Document de brevet cité dans le rapport de recherche	Datum der Veröffentlichung Publication date Date de publication	Mitglied(er) der Patentfamilie Patent family member(s) Membre(s) de la famille de brevets	Datum der Veröffentlichung Publication date Date de publication
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